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and it was found that, as a rule, the expansions and contractions were in the same direction as for the transverse measurements, but yet this was not always the case. The changes in circumference were found not to be proportional to the transverse measurements. After more than four months, when the temperature was much higher than at the time observations were begun, the circumference of the tree was still *smaller* than when the first observations were made. The method of making observations on the circumference consisted in measuring, with a pair of dividers, the distance between two scratches on a painted steel tape surrounding the tree, and continuously left in contact with it. When the series of observations was begun, two scratches were made, one on each of the two parts of the tape which lay, one directly above the other, and, as the circumference changed, the distance between these scratches was recorded. These measurements were made several times a day, and showed that the final contraction, which Grossenbacher² thought might possibly be due to an error in his measurements, is an actual experimental fact. Grossenbacher's observations were made at intervals of several weeks, and his tape was removed after each observation.

An equally extended series of measurements on frost cracks was made during the winter of 1917-18. It was found that during the coldest weather when the crack was open about three fourths of an inch, its depth at certain points was more than ten inches. Also, in addition to the large crack formed on the south side of the linden tree, another was formed on the north side toward the end of January, 1918, and the change in the width of the two cracks seemed to follow the same law, *i. e.*, the cracks became wider as the temperature fell, and narrower as it rose again.

From the measurements on the transverse changes, on the circumference and on frost cracks, the conclusion was reached that frost

cracks are caused by a tearing apart of the tissue of the tree, due to a great *contraction*. Both the circumference and the transverse dimensions are much less when the crack is open than when it is closed, and the one is not proportional to the other.³ Frost cracks are probably due to a difference in the coefficients of radial and tangential contraction of the tree, a difference which sets in at approximately 25° Fahrenheit (about 4 degrees below zero Centigrade). If the cells of the tree collapse in a tangential direction (a fact which was observed) and the changes along the medullary rays are not as great, then the tree will split open, due to the increased tension. If the cells again expand tangentially, the crack will close due to increased pressure, provided the radius may not change in dimensions at all, it may expand to a greater extent, or it may even contract; in any case the crack will close. The first or third of these cases would account for the observation that after the crack has closed, the circumference of the tree is less than before it opened. These conclusions are, however, tentative and approximate, due to the complications caused by the lag in the tangential direction, the temperature gradient through the tree, and other difficulties which must still be studied, before a more complete explanation can be given.

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THE DEPTH OF DOLOMITIZATION¹

IN a recent issue of the *American Journal of Science*,² there appeared an article by E. W. Skeats on "The Formation of Dolomite and its Bearing on the Coral Reef Problem." The author of this paper adopts the replacement theory of the origin of dolomite and presents

³ Some similar conclusions were reached by a different method by Caspany, *Bot. Zeit.*, 15, 1857.

⁴ Deceased.

¹ Published with the permission of the Director of the Iowa Geological Survey.

² Volume XLV., 4th Series, pp. 185-200, March, 1918.

²J. G. Grossenbacher, "Crown-Rot of Fruit Trees, Field Studies," N. Y. Agricultural Experiment Station, Geneva, N. Y., Technical Bulletin, No. 23, September, 1912, pp. 35-37.

evidence in favor of the view that regional dolomites are of shallow water origin. The bearing of this conclusion upon the coral reef problem is made clear from the following quotation:³

The author regards the evidence of dolomitization of fringing reefs of coral islands, the occurrence of dolomite immediately below phosphate beds, on the hill tops of Christmas Island, the rise in the magnesian content of the limestones of the Funafuti bore between 15 and 30 feet, as definite and strong evidence of the shallow water origin of dolomite in coral islands. It is claimed that this view is consistent with the chemical evidence quoted above of the reversal of the solubilities of calcium and magnesium carbonates in carbonated water between the pressures of one and four atmospheres. In addition, the evidence, cited above from more ancient dolomites showing their intimate associations with independent evidence of shallow water such as fossils, current bedding, conglomerates, and oolitic structures, is so consistent and so in accordance with the evidence from modern coral limestones, that the author takes the view that wherever a "contemporaneous" or regional dolomite is found to occur, it may be regarded as having originated in shallow water. If this be granted, it follows that such upraised coral islands, like Ngillangillah, now 510 feet high, and Vatu Vara, now 1,030 feet high, which are dolomitized from top to bottom, must have originally been formed of shallow water limestones accumulated by subsidence to at least 500 to 1,000 feet respectively before elevation set in. The atoll of Funafuti whose surface is practically at sea level must have been built up of shallow water limestones accumulated during subsidence, which must have amounted to about 1,100 feet at least since the cores from 635 feet to 1,114 feet consist entirely of limestones which have passed through the process of dolomitization.

In the writer's experience with regional dolomites of undoubted secondary origin, he has encountered considerable evidence in support of the contention that many of them represent shallow water deposits, but he is not yet prepared to conclude that all replacement dolomites are of this origin. The most striking evidence bearing on this question that has come to the writer's attention, has been obtained in connection with his study of the

³ *Ibid.*, p. 200.

limestones of the Osage and Meramec series, of Mississippian age, in the Mississippi Valley.

In Ste Genevieve county of southeastern Missouri, these limestones, with one exception, possess all the ear-marks of clear, open sea deposits (see table). They attain their maxi-

TABLE

Series	Name of Formation	Thickness in Feet
Meramec	Saint Louis limestone	150
	Spergen limestone	160
Osage....	Warsaw formation	150
	Keokuk limestone	30-40
	Burlington limestone	75

imum development there, are all, with the exception of the Warsaw, unusually pure, and, barring a small break of local significance at the base of the Warsaw, are conformable. The paucity of dolomite in this thick series of limestones is remarkable. With the exception of an impure bed of dolomititic limestone in the upper portion of the Warsaw, which may well be of elastic origin, and a thin, imperfectly dolomitized layer in the Saint Louis at the station of Little Rock, no dolomite was observed during a careful study of the whole section.

In southeastern Iowa and adjacent portions of Illinois, on the other hand, very different conditions are met with. In this region all the formations show indications of having been deposited in shallow, oscillating seas, the evidence being most pronounced in the Spergen and Saint Louis limestones, and dolomite is a very important constituent of every member of the series.

The Burlington limestone maintains approximately the same thickness here as in southeastern Missouri, but beds of brownish, impure dolomite, some of which pass locally into shale, are interbedded with the limestone and constitute more than fifty per cent. of the formation.

The Keokuk consists of interbedded layers of shale and limestone, some of the latter being dolomitized locally; and the Warsaw is made up chiefly of argillaceous shale but bears occasional lenticular beds of limestone, some of which are imperfectly dolomitized.

The Spergen limestone of southeastern Iowa

is very different from that of southeastern Missouri, and much confusion attended the earlier attempts to refer this formation to its proper position in the series. This confusion was evidently due, in large part, to the failure of earlier workers to recognize the disconformities at the base and at the top of the formation. The apparent tendency of the Spergen to grade laterally into the Warsaw or the Saint Louis has resulted entirely from these relationships. In addition, the Spergen is very variable in lithologic character in this region, due in part to original conditions of sedimentation, and in part to differences in the degree of dolomitization. It is not uncommon to find a cross-bedded, crinoidal limestone passing laterally within a short distance through imperfectly dolomitized limestone into massive, brown dolomite, and this again into a brownish arenaceous dolomite, which may in turn give way to a fine-grained, bluish sandstone. Such rapid changes clearly indicate near-shore conditions during deposition. This is also suggested by the limited extent of the formation in Iowa, and by its rapid thinning to the northwest. Its thickness in this region varies from 0 to 35 feet.

The Saint Louis limestone of Iowa also shows marked evidence of shallow conditions during deposition, although it has a much more widespread distribution than the Spergen. It consists of two distinct subdivisions separated from one another by a disconformity. For convenience these may be designated as the Lower Saint Louis and the Upper Saint Louis. The Lower Saint Louis is by far the most extensive of the two members. This extends far to the northward, overlapping all the earlier formations of the Mississippian except the Kinderhook, upon which it rests in Humboldt county. It consists for the most part of massive beds of compact, dolomitic limestone, but frequently these are found to grade laterally into gray, non-dolomitic limestone within short distances. At most localities, the lower beds are arenaceous. Ripple marks and cross-bedding may appear locally at any horizon. In southeastern Iowa, mound-like reefs of limestone with undisturbed layers lapping up on

their flanks are occasionally found in the formation. These were evidently formed by wave action during deposition. The thickness of this division is about thirty feet. The Upper Saint Louis consists for the most part of light gray compact limestone which is locally dolomitized either wholly or in part, and shows the same evidence of shallow water deposition as the Lower. Locally this division passes laterally into sandstone in part. The Upper Saint Louis seldom exceeds twenty-five feet in thickness.

The writer has observed further evidence of the relation of the extensive dolomitization to the shallow water zone in the Cedar Valley limestone, of Upper Devonian age, in Iowa. In Johnson county, which is located a short distance south of the east-central portion of the state, this formation has an exposed thickness of approximately one hundred feet and consists of fairly pure, gray fossiliferous limestone almost entirely devoid of dolomite. But in Mitchell, Howard, Winneshiek and other counties in the northern portion of the state, the Cedar Valley is made up of interbedded limestone and dolomite, and bears evidence of having been deposited in shallow seas. The beds are impure, shaly partings are common between the layers, and evidences of contemporaneous erosion are frequently encountered.

The suggestion is ventured that careful study of other Paleozoic limestones will disclose similar evidence of more extensive dolomitization in their shallow water facies.

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